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# A Comparison of the Effects of the Chernobyl and Three Mile Island Nuclear Accidents on the U.S. Electric Utility Industry

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## Çernobil ve Three Mile Island Nükleer Kazalarının Amerikan Elektrik Şirketleri Üzerindeki Etkilerinin Karşılaştırılması

**Abstract**

We examined the stock market reaction to two nuclear accidents, the Three Mile Island incident and the Chernobyl disaster. We were interested in determining whether the negative stock market reaction following these events was consistently related to the level of nuclear exposure by each firm and whether the negative reaction was reasonably linked to human safety concerns. Prior research has shown that following TMI, but anomalously not Chernobyl, firms with the more nuclear capacity experienced larger stock price declines. Moreover, the link of safety to stock market reaction has not been investigated for either accident. Firms with higher nuclear exposure and already in trouble with NRC lost more than others in stock market. Likewise, firms having nuclear reactors close to populated cities lost more in stock market.

**Key Words** : Event Study, Nuclear Accidents, Electric Utility Stocks.

**JEL Classification Codes** : G14, E44, D23.

**Özet**

Yeryüzünde ki iki büyük nükleer felaket olan, Three Mile Island ve Çernobil nükleer kazalarına borsanın verdiği tepkiyi inceledik. Borsanın bu kazalara karşı negatif tepkisinin her bir firmanın nükleer payı ile orantılı olup olmadığını ve bu negatif tepkinin halkın güvenliği ile makul ölçülerde ilişkili olup olmadığını araştırdık. Literatür de TMI için böyle çalışmalar yapılmakla birlikte, Çernobil için daha once yapılmamış ve borsanın halk güvenliğine verdiği negatif tepki araştırılmamıştır. Nükleer kapasitesi yüksek olan ve regülatör ile problemleri olan firmaların hisseleri diğerlerine göre daha fazla düşmüştür. Aynı şekilde, nükleer santralleri kalabalık yerleşim yerlerinde olan firmalar borsa da daha fazla kaybetmişlerdir.

**Anahtar Sözcükler** : Olay Çalışması, Nükleer Kazalar, Elektrik Şirket Hisseleri.

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## 1. Introduction

This paper analyzes the impact of the 1986 Chernobyl nuclear accident on the equity values of firms in the U.S. electric utility industry and compares the impact of Chernobyl accident with that of Three Mile Island (TMI) nuclear accident that occurred in 1979. The Chernobyl nuclear accident was one of the most devastating industrial disasters ever experienced. It disrupted the lives of hundreds of thousand people in the Ukraine. It created global concern over the widespread use of nuclear energy. Even after many years, the nuclear industry worldwide has not completely overcome the trauma of this disaster. Thus, it is likely that a nuclear accident of such scale also had a significant effect on the U.S. electric industry where nuclear energy was at the time one of the major sources of electric power.

Prior studies have looked at the stock price reactions to both the Chernobyl and TMI nuclear accidents. In both cases the U.S. electric industry lost equity value. However, the results of these prior studies are incomplete and anomalous. Analysis of the Chernobyl event did not find a consistent relation between nuclear involvement and the negative stock price reaction. Furthermore, in neither case has there been an investigation of whether there was a systematic relation between the stock price reactions and objective safety concerns. The purpose of this research is to fill this gap in the literature.

## 2. The Events & Prior Studies

### 2.1. Chernobyl

The nuclear disaster occurred in the early morning of Saturday, April 26, 1986 (1:24 AM local time) as a result of a botched safety drill. The world became aware of the accident 2 days later. The details of chronological sequence of major events following the Chernobyl accident are compiled by Kalra, Henderson, and Raines (1993), and Pruitt, Tawarangkoon, and Wei (1987).

At the time, there was a public debate going on in the U.S. about whether or not to reduce the evacuation zone around nuclear plants from 10 miles to 5 miles. The Chernobyl nuclear accident fueled the skepticism of the environmental groups and the general public about relaxing such safety rules.

As of January 1, 1986 there were 99 nuclear power plants operating and 32 nuclear reactors were under construction in the U.S.[1] At that time, the U.S. had about 30

[1] *The Wall Street Journal, p. 24, April 30, 1986.*

percent of the total worldwide operating nuclear reactors. However, the basic designs of U.S. nuclear power plants were different from that of the Chernobyl type of nuclear reactors. The nuclear reactors at Chernobyl, and also in most parts of the USSR, were based on the graphite cooling system, whereas almost all of nuclear reactors in the U.S. were based on the water cooling system. The water cooling system of a nuclear plant was considered to be relatively safer than the graphite cooling system.

Likewise, emergency measures had not been strictly enforced while establishing such nuclear power plants in the Soviet Union due to lack of involvement of local people and the absence of public participation on such decisions. The Chernobyl disaster was caused by human error in the exercise of an emergency practice drill. When the disaster occurred, evacuation of the area was slow and many people died as a consequence.

It was certain that the Soviet disaster was likely to have a large negative impact on the worldwide nuclear power business. The Wall Street Journal on April 30, 1986, reported that most of the spokespersons of U.S. electric utility companies raised concerns over the Chernobyl nuclear accident and predicted likely political and public pressures against nuclear power plants in the U.S. (p. 24). It was equally certain that the critics of nuclear reactors and environmental groups would cite the Chernobyl nuclear disaster as a strong evidence for their arguments against the excessive use of nuclear power plants in the future.

Value Line *Investment Survey* (May 9, 1986) reported that the price index of Value Line Composite Index, S&P 500 index, and the Dow Jones Industrial average index fell by 2.7 percent, 2.8 percent and 2.9 percent respectively for the week ending May 1. Furthermore, Value Line also reported that the share value of the heavy oil industry went up on the investors' perception of likely positive impact on the substitute of nuclear-fuel. In addition to the electric industry, the grain market of the U.S. also reacted sharply over the news of the Chernobyl nuclear accident, since the radioactivity from the Chernobyl plant had been spread over one of the major grain producing belts of the USSR.

The Wall Street Journal (April 30, 1986) reported that the nuclear accident also caused the price index of the future grain market, and the commodity prices in the U.S. to spurt up on the assumption of likely uncertainty on the global food supply. USSR was then one of the major importers of the grains, sugar, and often meat from the world commodity markets, and the nuclear accident had affected one of the major grains producing regions in the USSR. The grain market reaction was consistent with market efficiency. Large volatility in the commodity future prices following the Pruitt, Tawarangkoon, and Wei et. al. (1987) reported that there was a Chernobyl event in those commodities produced in the Chernobyl region. This volatility was statistically significant, short-lived, and did not lead to increased volatility in unrelated commodities. It seems that the security market reacted quickly to information about the disaster.

Kalra, Henderson, and Raines (et. al., 1993) analyzed that the impact of the Chernobyl nuclear accident on U.S. utility industries using event study methodology. They used 71 publicly traded firms from the list of public power utilities (SIC code 4911) that were traded in NYSE. They split the sample into three categories: nuclear (20 percent or more of nuclear share), mixed (utility under 20 percent of nuclear power) and convention (firms with no nuclear capacity). The firms in each of the category were: 20 in nuclear, 16 in mixed and 33 in conventional-generation portfolio. They reported that over all there was a negative price reaction due to the nuclear accident. However, most pronounced impacts were seen on the mixed utilities, that is, firms with between zero and 20 percent nuclear capacity and not the higher nuclear capacity firms. The study does not elaborate on this result, which we consider to be an anomaly.

### 2.2. Three Mile Island

On Wednesday, March 28, 1979, a nuclear accident occurred at Three-Mile Island (TMI), the first major nuclear accident in the U.S. history. This intensified public concerns and also increased regulatory measures on operation of nuclear plants. As it would be expected a number of antinuclear measures were introduced in U.S. Congress after the Three Mile Island accident. Duffy (1997), Bowen, Castanias, and Daley (1983) analyzed that the impact of Three Mile Island accident on the U.S. electric industry using event study methodology. They show the impact of the Three Mile Island accident on the stock returns of the publicly traded electric utilities.

Bowen, Castanias, and Daley (*et. al*., 1983) found that a significant change on the utility stock prices during the event window and over the post event period depending on the scale of nuclear exposure or level of nuclear capacity. The firms with higher nuclear capacity lost more. The average relative price change for the entire sample (83 utility companies) was -4 percent by the end of five weeks from the Three Mile Island event. Those firms with at least 20 percent of their capacity produced by the nuclear energy lost 6.6 percent of their asset value by the end of five weeks from the event. Furthermore, the firms that were operating nuclear facilities built by the Babcock & Wilcox (BW) company, the company that built the Three Mile Island nuclear plant earlier, on average lost 6.9 percent of their asset value by the end of the five weeks from the Three Mile Island event. Bowen, Castanias, and Daley (*et. al*., 1983) reported that the overall riskiness of utility shares during the post-TMI event period was significantly increased for the utility industry, particularly for the utility companies that had a larger nuclear share and/or the utility companies that were operating the nuclear facilities built by BW.

Hill and Schneeweis (1983) stated that firms with the largest nuclear exposure had the most negative abnormal returns during the TMI event. They selected 64 utility firms with two-portfolio categories, 30 non-nuclear and 34 nuclear-based utility firms, whose common stock was traded on the NYSE for the period. Likewise, Barrett, Heuson, and Kolb (1986) analyzing the effect of TMI on bond risk premia in the public utility industry reported that there was an industry-wide effect resulting from TMI on the risk premia that is independent of the nuclear power generation. They found a statistical significant increased in the risk premia attached to all electric utility bonds, but the firms possessing nuclear generating capacity had a much larger increase in the risk premia after the TMI event than non-nuclear utility bonds.

### 2.3. Other Major Concerns about the Nuclear Industry

There is no doubt that the Three Mile Island accident created a significant political damage to the nuclear power industry in the U.S. Public protest as well as congressional regulations on the nuclear industry largely increased thereafter. Many who were positive about nuclear power before the accident changed their view. Following the Three Mile Island accident, Nealey (1990: 51) reported that the public opinion polls conducted in the U.S. showed that the public did not feel the accident was a freak occurrence and felt that it could happen again.

Even so, nuclear power was still a potentially valuable source of electricity in the U.S., more so in the early 1980s during the oil crisis era. Duffy et. al. (1997) reported that President Carter said that although safety was his “top priority,” “we cannot shut the door on nuclear power for the U.S.” since it is “critical if we are to free our country from its over dependence on unstable sources of high-priced foreign oil”

We may not be able to precisely predict all of the long-term effects the Chernobyl accident had on the nuclear power industry in the U.S. However, the news reports and/or public opinion surveys done at the time showed that like Three Mile Island, Chernobyl left an everlasting legacy of doubt about nuclear power safety worldwide. Nealey (*et. al*. 1990: 53) reported that a survey by ABC News found that 58 percent of respondents were “more fearful” because of Chernobyl that an accident of a similar kind could happen in the country. Likewise, many responded they felt that the risk of such accident had increased worldwide. In addition, there was also debate going on at that time whether to reduce the evacuation safety zone the nuclear plants from 10 miles radius to only 5 miles.

Not only the utility industry, but the insurance industry was also adversely affected by the nuclear accident, and was very much concerned with the complexities of writing nuclear liability insurance. The private nuclear insurance was ready to write some coverage, but it was reluctant to provide full liability protection in case of any accident due to high level of uncertainty involved. In fact, the cleanup cost for TMI accident alone was more than $1 billion, which was much higher than the liability limit of $660 million (with only $160 million from private insurance) set for each nuclear reactor by the Price-Anderson Act[2].

### 2.4. Relevance of This Study

Although our paper is similar to the Bowen, Castanias, and Daley (*et. al*., 1983) event study of TMI and Kalra, Henderson, and Raines (*et. al*., 1993) event study of Chernobyl, there are several new aspects worthy of consideration. We use a larger sample--all electric firms reported by Value Line for which stock market data are available at the times of the disasters. Our sample size for the Chernobyl event is total of 99 firms, which is 22 more firms than used by Kalra, Henderson, and Raines, (*et. al*., 1993).

In examining the Chernobyl accident, we split the sample into six sub-categories or portfolios which includes a portfolio for firms involved in construction of new nuclear plant and/or committed to new nuclear power capacity, and also a portfolio for firms having safety related trouble with Nuclear Regulatory Commission (NRC). After adopting the standard event study procedure, we extend the study to explain how the abnormal stock returns are related to firm specific factors such as the firm's existing nuclear capacity as well as construction in progress and its experience with the NRC. The same analysis is performed using the abnormal stock returns following the TMI incident.

In particular, we measure the direct safety threat of a nuclear accident for each firm by calculating the population that would be exposed in the case of a mishap. Reasonably, firms whose nuclear facilities pose a larger threat to human safety should have fared worse following both of these nuclear accidents.

## 3. Data and Analytical Procedures

Our first order of business is to re-examine the stock market performance of electric utilities following the Chernobyl accident. We do this because the results of the prior study are not wholly consistent with our expectations. To do this, all publicly traded electric utilities covered by Value Line in May and June 1986 (101 firms) were selected for the event analysis in this study. However, due to non-trading of some of the utility stocks during the event windows period, and unavailability of return data, two firms were dropped from the final sample.[3] A total of 99 publicly traded U.S. electric utility firms were selected for the event study purpose. These utility firms were sub-categorized based

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[2] *Business Insurance, September 28, 1981.*

[3] *Information on nuclear capacity, plants under construction, and information about dealings with the NRC and state commissions were obtained from the Value Line* Investor Surveys *of April, May, and June, 1986. Asset prices and returns were obtained from the Center for Research in Security Prices (CRSP).*

on the level of nuclear exposure to analyze details of intra-industry changes brought by the event in question. All the firm-related information was collected from Value Line surveys of April, May, and June 1986. Value Line reports the "percentage of fuel use by source type" from which we calculated the share of nuclear power in total generation.

Out of the selected sample of 99 utility firms, 37 firms had no nuclear generation at the time. These firms had neither current exposure nor any commitment to nuclear power in the near future. The remaining 62 firms in the sample had different levels of nuclear capacity and nuclear exposure in terms of existing plants, construction, and experiences with the NRC. They are sub-grouped into five different categories depending upon the level of nuclear exposure.

**Table 1**
**Sub-samples of U.S. Electric Utility Companies Selected for the Chernobyl Event Study**

| Category of Electric Utility Firms by Nuclear Fuel Use Type | Nuclear Power as Percent of Fuel Use | Total Number of Firms |
|---|---|---|
| LN= Large nuclear capacity | Greater than 40% | 6 |
| MN= Medium nuclear capacity | Less than 40% and greater than 20% | 13 |
| SN= Small nuclear capacity | Less than 20% | 11 |
| NN= No nuclear capacity | without nuclear capacity | 37 |
| UCN= Under construction of nuclear power plants | Some with existing nuclear capacity; some without | 27 |
| ATNRC= Already trouble with NRC | Past trouble with NRC or case pending | 17 |
| ALL= All firms in sample (avoiding duplications) | | 99 |

Nuclear firms are grouped into small, medium, and large based on the amount of nuclear generating capacity relative to other generation assets. There are also two other categories: firms with nuclear plants under construction at the time, and firms that had already had difficulties at the NRC or had cases pending before the NRC or cases pending before state commissions in regard to nuclear plant cost recovery. There is duplication between groups because most firms with nuclear plants under construction had existing nuclear capacity and because only firms with existing plants or plants under construction had had dealings with the NRC. The number of firms in each group at the time of the Chernobyl event is given in Table 1.

The same data-collection procedure and same set of variables are used to examine the impact of the TMI accident in 1979. There were 88 publicly traded electric utilities covered by Value Line in 1979. Data on nuclear capacity in operation, under construction, and planned as well as information on regulatory matters and other financial information were taken from Value Line, 1979.

The information on population residing within 10 miles and 5 miles radius of nuclear reactor (plant) is provided by NRC, but data are only available after 1990.[4] Thus, we use the same population data for both the Chernobyl and TMI accidents.

### 3.1. Estimation of Abnormal Returns

We examine the stock price reaction to the two disasters in the context of the standard market model of stock prices.[5] The market's reaction to the disaster is incorporated into this model by including a dummy variable for the days over which the event is expected to have been assessed by investors. That is,

$$R_{it} = \alpha_i + \beta_i R_{mt} + \gamma_i D_\theta + \eta_{it} \tag{1}$$

where $R_{it}$ is the rate of return on security *i* over time period *t*, $R_{mt}$ = rate of return on all the of stocks traded in the market, $\eta$ is an error term with zero mean and constant variance, and $D_\theta$ is a dummy variable and $\theta$ is the event window time period. $D_\theta$ equals one during the period of the news announcement and zero otherwise.

Equation (1) can be estimated separately for the *i* firms, or jointly. When estimated jointly, it is common to allow for different intercepts and beta coefficients for each firm. The coefficient $\gamma$ is the average abnormal return for each day during the event period. If the regression is estimated for all firms jointly, the coefficient measures the average abnormal return over all firms.

Equation (1) assumes that there is no change in the value of beta as a result of the event. However, the model can be augmented to account for this effect. Variation in the beta parameter after the event can be examined by allowing for a shift parameter and estimating the market model on both sides of the event, i.e.,

$$R_{it} = \alpha_i + \beta_{i\,pre} R_{mt} + \beta_{i\,post} R_{mt} + \gamma_i D_\theta + \eta_{it}. \tag{2}$$

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[4] *The population residing within a five and ten mile radius of each nuclear plant is available from NRC web pages.*

[5] *MacKinlay (1997) summarizes details on the theoretical and methodological aspects of event study techniques, and some of the recent literature.*

### 3.2. Event Window and Information Availability

The Chernobyl nuclear accident occurred in the early morning (1:24 AM) of Saturday April 26th, 1986, but the news about the nuclear accident only became widely known in the U.S. on Tuesday, April 29th, 1986, through in a small headline in the Wall Street Journal. Nothing was mentioned about Chernobyl in the previous issue (April, 28th, 1986) of the Wall Street Journal, but it is fair to assume that news about the nuclear accident could have reached the security market on Monday afternoon (April 28th), which was also the first day that the market was open following the accident. Therefore, April 28th is assumed here as the beginning of the window of time over which the stock market reaction is measured.

The news about the full impacts and scale of the nuclear accident became available only gradually on the subsequent days. To capture the full impact of the event on the security prices, event windows of three days is used: Monday, April 28th, through Wednesday, April 30. That is, the dummy variable $D_{\theta}$ from equation (1) takes a value of 1 on these days. The cumulative average abnormal returns (CAAR) are estimated by the coefficient $\gamma_i$ on the dummy variable.[6]

The market parameters, $\beta$ and per day mean returns for both pre- and post-event periods were estimated from the data of 200 market days excluding the nearest 17 market days from each pre and post event date. This allows estimation of the beta for each firm excluding the impact of event period volatility on the security market.

The TMI accident occurred around 4a.m. on Wednesday, March 28, 1979. The news of the accident was made public that same day. However, the extent of the accident was not known for several days. Even on Saturday, March 31, there was still a threat that the reactor containment chamber could blow up. Because of the uncertainty about the extent of the accident, we use a 4 day window for the TMI incident that extends through Monday, April 2.

### 3.3. Regression Analysis

To more fully explore the results, the CAARs estimated for each firm are regressed on the characteristics of each firm. These characteristics include population density in the 10 miles surrounding each of the firm's nuclear power plants, nuclear capacity of the firm as a percent of total generating capacity, the firm's debt-equity ratio, load factor, and two dummy variables, one representing nuclear capacity under construction and another representing prior trouble at the NRC.

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[6] *Longer event windows were used but the results are unaffected. The standard event-study methodology assumes that the information of an event is almost immediately embedded in an event.*

Out of the 99 firms in the Chernobyl sample, only 95 firms were used for the regression analysis. Four firms were dropped from the regression analysis since the nuclear plants they owned in 1986 were closed thereafter and the population-related information for these nuclear plants is not now available from the NRC. The firm level population number was obtained by averaging the neighboring population for all of the nuclear plants that a particular firm owned or has a stake in.

The same regression analysis and same set of variables are used to examine the impact of the 1979 TMI accident. We use the 4-day CAARs of the 88 publicly traded electric utilities covered by Value Line in 1979.

## 4. Hypotheses

Event study methodology analyzes the stock price reaction of a firm or industry during an event period based on some underlying hypotheses about the nature of the event. In the case of the two nuclear disasters, we expect that firms in the U.S. with nuclear generating facilities should have experienced stock price declines.

Our attention is focused on several specific questions:

1) Was the stock market reaction to the Chernobyl event consistently related to the extent of nuclear exposure for each firm?

2) Was there a change in the stock market risk factor in the industry as a result of the Chernobyl event?

3) Was the stock market reaction to either the TMI or Chernobyl events systematically related to measurable human safety threats?

It would be most reasonable that the market reacted more negatively for firms with larger nuclear exposure more than firms with smaller nuclear interests. This is what prior research found after the TMI incident, but the same result has not been uncovered following the Chernobyl disaster. It is likely that researchers studying the Chernobyl event were not careful enough in categorizing the nuclear exposure of firms. Hence, we return to this inquiry.

For firms involved in construction of nuclear power plants it was likely that the Nuclear Regulatory Commission (NRC) would further tighten its regulations and licensing procedures for operation and management of such plants in the aftermath of the Chernobyl disaster, so this group should have fared especially badly. Likewise, it is possible that those firms that were already having trouble with the NRC regarding operating, licensing, and safety issues of nuclear power plants would have more negative stock market reactions. We account for these factors as well.

The Chernobyl accident was one of the most devastating industrial accidents that have occurred to date. As a result of the accident it is possible that the overall structure of the U.S. electric industry might have been changed and in particular the industry's overall stock market risk. We examine this by looking for changes in the market betas of the electric utilities. If this stock market risk shift did occur, it should have been larger for the firms with the most nuclear exposure and should not have occurred for firms with no nuclear capacity.

Due to the scale and nature of the Chernobyl nuclear accident and the controversy over the NRC's mass evacuation regulations in case of a nuclear accident, the population density around nuclear power plants could also be one of the factors influencing the market's reaction. There was a significant outcry over an NRC proposal to reduce the mass evacuation zone limit from 10 miles to 5 miles. Therefore, it was also likely that the market would have reacted more strongly to those firms located too close to the densely populated areas, particularly, if there is any town or city located within the 5 miles of mass evacuation zones of the nuclear plants. We examine this phenomenon for both the Chernobyl disaster and the TMI incident.

## 5. Results

### 5.1. Abnormal Returns in the Aftermath of the Chernobyl Accident

The results presented in Table 2 indicate that the cumulative average abnormal returns (CAAR) for the entire sample, that is, all U.S. electric firms, fell by 2.12 percent over the three-day event window period relative to the market. When the news about the Chernobyl nuclear accident first appeared in the Wall Street Journals on April 29th, 1986, the asset value of the electric firms as a whole fell by on an average of 1.17 percent (significant at the 1 percent level). This means the Chernobyl nuclear accident produced a significant negative impact on asset value of U.S. electric industry of over $7 billion.

The average abnormal returns (AAR) and the cumulative average abnormal returns (CAAR) are not equal across the different categories of the electric firms selected in the sample. As shown in the Table 2, utilities already in trouble with the NRC, with cases pending at the NRC or at state regulatory commission regarding the safety issues of nuclear power plants, rate determination, or allowances for nuclear power plants suffered the largest equity declines during the event window. This group on average lost 2.27 percent of equity value on April 29 and 5.6 percent loss during the three-day event window.

**Table 2**
**Market Adjusted Abnormal Return for Selected Categories of Electric Utility Firms during the Event Window Periods following the Chernobyl Accident.**

| Firm's Category Based on Nuclear Exposure Level | Market Adjusted Average Abnormal Returns (AR) on April 29th, 1986 | Cumulative Average Abnormal Returns (CAAR) During April 28-May 1, 4 Day Event Window |
|---|---|---|
| LN=Greater than 40% | -1.59%*** | -2.64%*** |
| MN=Greater than 20% and less than 40% | -1.27%*** | -1.91%** |
| SM=Less than 20% | -0.55% NS | -1.59% * |
| NN=No nuclear capacity | -0.61% NS | -0.24% NS |
| UCN=Under construction | -1.91%**** | -4.50% **** |
| ATNRC=Trouble with NRC | -2.27% **** | -5.59% **** |
| ALL=All Firms in sample | -1.17%*** | -2.12%*** |

Notes:
**** = Significance at 0.1% level; **= Significance at 5% level; NS= Not significant even at 10% level
*** = Significance at 1% level; *= Significance at 10% level

The coefficients on the level of nuclear exposure show the expected pattern. The more nuclear capacity that a firm had in place, the more negative was the stock market reaction. This is consistent with our expectations and resolves the anomalous finding of Kalra, Henderson, and Raines (*et. al*., 1993). While the coefficients themselves are not statistically significantly different from each other using a simple difference in the means test, a more precise statistical test is performed by regressing the CAARs on the level of nuclear exposure across the sample. By means of the regression analysis we can control for other firm specific factors affecting the CAARs, most importantly, nuclear capacity under construction and existing regulatory woes.

***Most affected firms***

Eastern Utility Associated had nuclear capacity of 26 percent at that time. In addition, it had on going problems and delayed commercial start-up of the Seabrook #1 nuclear power plant. Value Line (May, 1986, page 192) reported that the commercial start-up date of Seabrook #1 plant had been pushed back because of unresolved problems with the emergency evacuation plan. The managers of Seabrook #1 plant did not expect the commercial start-up of this unit until the spring of 1987 at the earliest, five months later than the previous forecast. In spite of these problems, Eastern had committed to increase its involvement in Seabrook #1.United Illuminating Company had only 8 percent nuclear capacity at that time. However, the company was deeply involved in the Seebrook #1 nuclear plant along with Eastern Utilities. Other hard hit firms were Public Service Company of NH (-7.5 percent), Rochester Gas & Electric (-8 percent), both in the ATNRC category.

Next hardest hits were firms with nuclear power plants already under construction. This group of firms on an average lost 4.5 percent of equity value during the 3-day event window (significant at 0.1 percent level). Some of the firms in this category were severely punished by the market: Atlantic City Electric (-7.5 percent), AZP Group (-7 percent), El Paso Electric (-6 percent), Middle South Utility (-6 percent), and Niagara Mohawk (-5.75 percent) . Of course, the earlier two hardest hit firms, Eastern and United Illuminating are also included in this sub-sample as their plant was still in the construction stage.

Value Line (May 1986) reported that Atlantic City (nuclear capacity 32 percent) was involved in Hope Creak nuclear power plant, and it had also petitioned at the state public utility commission to raise the rate cap for the increased construction costs on the plant. Likewise, the AZP Group was involved in Palo Verdo 2 nuclear plant, which was target for commercial operation in the following September of 1986. Power plant testing up to 100 percent capacity was then underway. Similarly, AZP had filled an adjustment application to the state commission requesting for higher rates to reflect the balance of unit 1's cost.

Value Line also reported that Public Service Co. of NH (nuclear capacity of 10 percent) had a 35 percent interest in the Seabrook #1 unit in which it had already invested in excess of 1.30 billion. Recovery of the utility's $300 million investment in Seabrook #2 was also in doubt at that time. Similarly, Niagara Mohawk was involved in Nine Mile Point #2 nuclear plant; commercial operation was the chief concern at that time. The plant's operation testing up to 100 percent of capacity was scheduled in mid of 1987. Moreover, Niagara Mohawk had also petitioned at the regulators for recovery of its 41 percent investment in the unit. Arguably, the market perceived that all these cases would be negatively affected by the Chernobyl accident.

As expected, the category of the firms having large nuclear capacity (more than 40 percent) lost about 1.6 percent of their asset value on the day the news about the event appeared in the Wall Street Journal (April 29$^{th}$, 1986). Also, the three-day CAAR for the large-nuclear group was -2.64 percent and statistically significant at the 1 percent level. Among firms in this sub sample, Boston Edison Co. (40 percent nuclear capacity) lost 4.36 percent and Iowa-Illinois Gas (47 percent nuclear) lost 4.0 percent within the three day event window.

The other sub-sample of utility firms, medium and small nuclear capacity, lost an average of 1.91 percent and 1.59 percent respectively of their equity value. The CAAR of small-nuclear category is statistically significant only at the 10 percent level. Some of the firms in the small-nuclear sub sample, such as Kansas City PWR and Kansas Gas & Electric, experienced equity value increases. The Wolf Creek nuclear plant, that these firms owned, had just gone into commercial operation in September, 1985. The market might have thought that recently built plants were relatively safer to operate than the others, or that newly approved facilities would receive little NRC scrutiny.

***The least affected firms***

Firms without nuclear exposure experienced no abnormal stock price reaction to the news of the Chernobyl disaster. The equity value of the no-nuclear portfolio decreased slightly (-0.24 percent) during the event windows but it is not statistically significant or economically meaningful. Out of 37 firms grouped into this category, the CAAR during the event window was positive for 12 firms. Firms like Utilicorp, United, Savanna Electric, Minnesota Power, indeed gained equity value by 3.55 percent, 2.94 percent, and 2.27 percent respectively.

The results on the table 2 clearly indicate that the event's impacts on the asset value of the electric firms varied according to the firms' nuclear exposures and their level of nuclear commitments. The higher the nuclear exposure or nuclear commitments, or the larger nuclear capacity the firms had, the more the reduction of asset values were.

**5.2. Risk Shifts**

Considering the nature and scale of the Chernobyl event, it is reasonable to investigate whether the Chernobyl nuclear accident caused a change in the fundamental riskiness of equity in the U.S. electric industry. To do this, we estimate portfolio betas for the different categories of electric firms grouped by nuclear exposure.

The results are presented in the Table 3. The beta for the portfolio of all firms fell by 2 percent from .96 to .94. There is no significant change in the betas that is consistent with a priori expectations about the event. The beta for the portfolio of firms heavily committed to nuclear power went up 8 percent while the firms with no nuclear capacity also went up by approximately the same amount. The firms with plants under construction seem to experience beta declines as did the portfolio of firms already experiencing regulatory concerns. Based on these results, we conclude that there was no significant change in the market beta coefficients as a result of the Chernobyl disaster.

**Table 3**
**Pre-event and Post-event Market Model Parameters**

| Firm's Category Based on Nuclear Exposure | Pre-event Beta | Post-event Beta | % Change |
|---|---|---|---|
| LN | 0.91 | 0.98 | +8 |
| MN | 0.89 | 0.93 | +5 |
| SN | 1.19 | 1.03 | -13 |
| NN | 0.85 | 0.909 | +7 |
| UCN | 1.03 | 0.920 | -11 |
| ATNRC | 1.087 | 0.95 | -13 |
| ALL | 0.96 | 0.94 | -2 |

Notes: Beta estimated over 200 day windows, 17 days before and after the event date.

### 5.3. Regression Results

Table 2 shows that firms with more nuclear capacity reacted more negatively to the news, and firms with plants under construction and firms already in trouble at the NRC had the largest negative stock price movements. We now investigate the extent to which these are independent factors. We also directly control for the safety concerns facing each firm. To do this we calculate the population within a five and ten mile radius of each plant. The results of the regression analysis are presented in details in Table 4.

**Table 4**
**Factors Affecting the CAAR During the Four-day Event Windows for the Chernobyl Accident in 1986.**

| Independent Variables | Ordinary Least Squares (Equation 1) | Heteroskedasticity Corrected, GLS (Equation 2) |
|---|---|---|
| Intercept | -0.220 | -0.643 |
| | (0.122)$^{NS}$ | (0.428)$^{NS}$ |
| Population within 10 mile radius | -2.61 | -1.14 |
| | (0.54)$^{NS}$ | (0.224)$^{NS}$ |
| Nuclear Capacity (in %) | -0.031 | -0.041 |
| | (2.070)* | (3.344)** |
| Firm's debt-equity ratio | 0.232 | 0.150 |
| | (0.532)$^{NS}$ | (0.427)$^{NS}$ |
| Firm's load factor (in %) | -0.017 | -0.007 |
| | (0.548)$^{NS}$ | (0.281)$^{NS}$ |
| <u>Dummy Variables</u> | | |
| Firms with nuclear capacity under construction | -1.893 | -1.999 |
| | (3.402)** | (3.30)** |
| Firms already in trouble at NRC | -2.537 | -2.38 |
| | (4.01)** | (2.62)** |
| $R^2$ | 0.45 | 0.27 |
| Observations | 95 | 95 |
| Mean of dependent variable | -2.37 | -2.37 |
| F- statistic | 12.02** | |
| White statistic ($\chi^2$ distribution at 5% level) | 61.22 | 39.55 |

Notes: t-statistics in parentheses below coefficients. ** significant at 1 percent level. * significant at 5 percent level. $^{NS}$ Not significant at 10% level. Population in millions of people. The P value of estimated White statistics of corrected model is 0.20 for 24 degrees of freedom and is not significant at acceptable level, which indicates that the regression results estimated from equation 2 is free from heteroskedasticity problem (Green, 2003: 221).

The dependent variable in Table 4 is the three-day abnormal return for each firm. The independent variables are population density within 10 miles of power plant, firm's nuclear capacity in percentage terms, firm's debt-equity ratio, and two separate dummy variables—one if the firm had nuclear plants under construction (UNC) and another if the firm was already in trouble at the NRC (ATNRC). Measuring nuclear capacity in percentage terms tests for continuity in the expected negative impact of the Chernobyl disaster on the operation of nuclear power plants in the U.S. Including population density investigates the extent to which firms expected increased regulatory scrutiny to be leveled most where the highest casualty risks were present.[7] We include the firm's debt-equity ratio and load factor as control variables.[8]

We test and correct for heteroskedasticity using White's method. The White test indicates that there is a heteroskedasticity problem in the regression model estimated as equation 1. Appropriate correction procedure was applied by dividing each variable of equation 1 by fitted error square term of the regression model, then the model is re-estimated (Green, *et. al*., 2003: 220). The re-estimated model is free from any such heterosckadesity problem, as given in equitation 2. White test is conducted again to confirm that the final regression model is free from any heteroskedasticity problem. The White Chi-squared value for the re-estimated model is 32.8 which is lower than the table value of 36.41 for 23 degrees of freedom at the 5 percent confidence level. Therefore, we can conclude that the regression results in equation 2 are free from heterosckadesity problem (Green, *et. al*., 2003: 221).

The $R^2$ of regression 2 is 0.39 and the F statistic (9.24) is significant at the 0.01 percent level. Considering the nature of the cross-section regression analysis, the relatively low goodness of fit is not a surprising result. The signs of all the estimated coefficients are consistent with our predictions as well as our economic intuition.

The coefficient for the 10 mile population variable is not statistically significant. This suggests that the stock market did not anticipate that increased regulatory scrutiny would fall disproportionately on firms in heavily populated areas or that nuclear disaster was, in fact, a serious threat. Presumably, if the Chernobyl disaster was the harbinger of tougher regulatory standards rationally based on legitimate safety concerns, the negative stock price effects should have been related to population. In addition to the results presented in the Table 4, we classified the population within 10 miles of the nuclear power plant into three sub-categories—less than 60,000; 60,000 to 100,000; and greater than 100,000. A shift dummy was tried for each category but none of the dummies for these sub-categories was statistically significant.

The nuclear capacity variable (in percent) is –0.039, and is statistically significant at 1 percent level. The sign of coefficient is consistent with economic intuition as well as the findings discussed earlier. The coefficient indicates that the larger the

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7 *We also used a 5-mile population measure. The results are identical for both.*

8 *Firm's with higher debt-equity ratios should have stronger reactions to a negative cash flow event.*

nuclear capacity of the firm, the larger the decline in asset value. The magnitude of the coefficient indicates that for each additional 10 percent of capacity made up by nuclear plants, the market revalued the equity of the company downward by .39 percent.

In addition, we included the debt-equity ratio to account for the effect of leverage on the equity revaluation. The simple correlation between the debt-equity ratio and CAAR is negative as we would expect. However, its coefficient in the regression is insignificant due to correlation with the other independent variables. Similarly, we included a variable measuring the excess generating capacity of the firm. The rationale for this variable is that the negative effect of the disaster should be lower the less capacity constrained was the firm. For firms with no nuclear exposure, the CAAR should be higher if they have excess capacity and if the disaster was expected to cause firms with high nuclear exposure to buy power from them at inflated prices. The estimated coefficient on the variable is statistically insignificant.[9]

The shift dummy coefficients for firms having trouble with NRC as well as those involved in construction of new nuclear plants are statistically significant at 1 percent level. The magnitude of dummy coefficient for firms having regulatory problems is higher in magnitude than that for firms with nuclear plants under construction, but both are large. The results presented in Table 4 are consistent with the findings presented in Table 2 and more powerful because they are the marginal effects of these two factors accounting for each other and the existing nuclear capacity of the firm. The predicted effect of the Chernobyl disaster on a firm with 40 percent nuclear capacity, nuclear capacity under construction, and already in trouble at the NRC is a decline in equity value of around 6 percent.

### 5.4. Chernobyl vs. TMI

The regression presented in Table 4 is replicated in Table 5 for the TMI event. The $R^2$ of the TMI regression is 0.48 and F statistic (12.56) is significant at the 0.01 percent level. Unlike the regression results in Table 4, the regression for TMI is free from heteroskadesticity problem (by White test). Therefore, no need to apply GLS estimation technique as done for Chernobyl case.

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[9] *We are also interacted both the debt-equity ratio and the excess capacity variables with nuclear exposure. Both variables remained statistically insignificant.*

**Table 5**
**Factors Affecting the CAAR During the Four-Day Event Windows for the TMI Accident, 1979.**

| Independent Variables | Equation 1 | Equation 2 |
|---|---|---|
| Intercept | -1.522<br>(1.399) | -1.264<br>(1.066) |
| Population with in 10 mile radius | -7.3<br>(1.69)* | -6.9<br>(1.67)* |
| Nuclear capacity (in %) | -0.049<br>(3.78)** | -0.05<br>(3.87)** |
| Firm's debt-equity ratio | 0.149<br>(0.724) | |
| Firm's load factor | 0.023<br>(1.177) | 0.024<br>(1.17) |
| Dummy Variables | | |
| Firms with nuclear capacity under construction | -1.446<br>(3.136)** | -1.441<br>(3.14)** |
| Firms with already in trouble at NRC | -2.590<br>(2.680)** | -2.611<br>(2.72)** |
| $R^2$ | 0.41 | 0.42 |
| Observations | 88.00 | 88.00 |
| Mean of Dependent Variable | -0.99 | -0.99 |
| F-statistic | 9.63** | 11.66** |

Notes: t-statistics in parentheses below coefficients. ** significant at 1 percent level. * significant at 10 percent level. $^{NS}$ Not significant at 10% level. Population in millions of people. We checked for the heteroskedasticity by White statistics test for both equations, which is not significant at acceptable level indicating that the models estimated are free from any heteroskedasticity problem (Green, *et. al.*, 2003: 221).

The most notable difference between the two events is the fact that the coefficient on the 10 mile population variable in TMI event, unlike in Chernobyl accident, is statistically significant at 10 percent level. The coefficient's magnitude in TMI event is nearly 20 times higher than the Chernobyl event. This means the stock market during the TMI event anticipated that increased regulatory cost would fall disproportionately on firms whose nuclear plants are located in heavily populated areas. Since, the liability of the firms in case of nuclear accident would increase due to additional burden on mass evacuation costs, and/or increased regulatory costs and increased insurance premium for the nuclear plant located in densely populated area. As a matter of fact, after the TMI accident and aftermath of the Chernobyl accident in 1986, the nuclear industry's annual insurance premium for accidental liability has been increased from $5 million per reactor to $10 million per reactor. In addition, the government has also raised the industry's liability (under Price-Anderson Act) for accident from $665 million before the Chernobyl accident to $7 billion in 1987 after the Chernobyl accident.[10]

The coefficient for the nuclear capacity variable (in percent) is –0.045, and is statistically significant at 1 percent level. The coefficient indicates that larger the nuclear capacity of the firm, larger the loss in the asset value. For the nuclear capacity rises by 10 percent, the market evaluated that equity of the company downward by 0.45 percent. This is also similar to the results of Chernobyl event given in table 4.

The shift dummy coefficients for firms having trouble with NRC as well as those already committed for nuclear power, or involved in construction of new nuclear plants are statistically significant at 1 percent level. The magnitude of dummy coefficient for the former is twice as high as the latter, but both are large compare to other coefficients, and the common intercept. The results in Table 5 for TMI event are consistent with the Chernobyl regression results presented in Table 4.

Debt-equity ratio coefficient is statistically significant but it does not carry the expected sign. The debt-equity ratio of the non-nuclear portfolio, that is, firms without any exposure to nuclear power, is on an average much higher than the portfolio with nuclear exposure. Hence, we think that this result is spurious. We re-estimate the model without the D/E variable. The signs and significance levels of the other variables are unchanged. The load factor variable for TMI event is not significant, but consistent with the expected sign.

Unlike previous studies, the marginal analysis of factors affecting the abnormal returns during the two events, as done here, provide a better picture of how the financial markets perceived those nuclear accidents and reevaluated the stock prices of the electric industry during the events.

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[10] *Science News (August 1, 1987), p. 70*

## 6. Conclusions

We examined the stock market reaction to two nuclear accidents, the Three Mile Island incident and the Chernobyl disaster. We were interested in determining whether the negative stock market reaction following these events was consistently related to the level of nuclear exposure by each firm and whether the negative reaction was reasonably linked to human safety concerns. Prior research has shown that following the TMI incident firms with the more nuclear capacity experienced larger stock price declines. However, this was not found in relation to the Chernobyl event. Moreover, the link of safety to stock market reaction has not been investigated in reference to either event.

Our findings support the expectation that the impact of the Chernobyl accident was relatively greater for firms with larger exposure to nuclear energy, for firms already having trouble with regulators regarding safety related issues of their nuclear power plants, and for firms with nuclear plants under construction. Based on the results presented here, we can conclude that the 1986 Chernobyl nuclear accident had a significant impact on the U.S. electric utility industry. News of the Chernobyl accident was followed by a reduction in equity value of more than $7.26 billion in the U.S. utility industry over the next three days.

The negative stock market reactions were greater, the more nuclear capacity employed by each firm. At the margin, ten percent additional nuclear capacity resulted in a .4 percent decline in equity value. The average loss for firms already in regulatory trouble was 2.27 percent of their equity value on the day the Wall Street Journal carried news of the event. This group lost a total of 5.6 percent of CAAR during the three days window following the news. The CAAR for firms with nuclear facilities under construction was -4.5 percent.

On the safety front, we find that the negative stock price movements following TMI were greater for firms with plants located near population centers. That is, firms that exposed a larger population to the threat of a nuclear accident saw their stock price tumble the most after TMI. However, the same was not true following Chernobyl. The coefficient relating exposed population to each firm's abnormal stock return at the time of the Chernobyl event is not significantly different from zero. Hence, the stock market anticipated that the regulatory fallout of the Chernobyl event would spread evenly across all nuclear plants.

This last point is a bit curious. It suggests that between TMI and Chernobyl, the political climate concerning nuclear power had shifted. One explanation of the differences in the stock market reaction to the two accidents is that by the time of Chernobyl or possibly because of it, nuclear power was essentially being regulated out of business in the U.S.

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